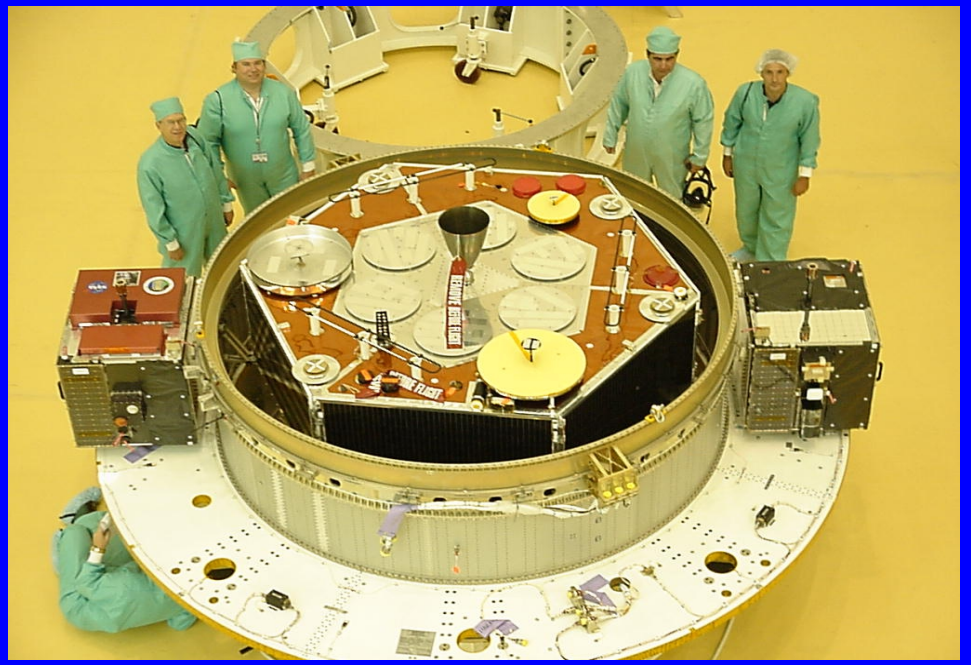
Five Decades of Amateur Radio Satellites - The history of AMSAT and a look at the future.

Daniel Schultz
n8fgv@amsat.org



Before you ask, nobody knows where the term HAM radio comes from. There are theories only.

What's the appeal of Ham Radio? Hams are at the cutting edge of many technologies. All of them enjoy being creators, not just consumers, of wireless technology.

Why don't we just use a cellphone to communicate? Just as people still enjoy going fishing even though it would be more cost effective to buy fish at the supermarket, hams seek the challenge of understanding the technology of radio by making it work for them. Amateur Radio is for the one kid in a thousand who wants to pry the lid off the box to understand how the magic really works.

Amateur radio has traditionally been an entry path for young people who eventually go on to technical careers as adults. Many aerospace engineers and a few astronauts and Nobel Prize winners began their careers as a radio “ham”. Ham radio provides much practical hands-on experience in communications and electronics that is simply not taught in an engineering classroom, and the amateur radio satellite program allows students to learn the practical aspects of spaceflight.

The definition of amateur radio is written in Federal law:

Title 47 – Part 97 Subpart A—General Provisions

§ 97.3 Definitions.

(4) Amateur service. A radiocommunication service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest.

§ 97.113 Prohibited Transmissions

(a) No amateur station shall transmit:

(2) Communications for hire or for material compensation, direct or indirect, paid or promised, except as otherwise provided in these rules.

(3) Communications in which the station licensee or control operator has a pecuniary interest, including communications on behalf of an employer.

(4) Messages encoded for the purpose of obscuring their meaning, except as otherwise provided herein;

(5) Communications, on a regular basis, which could reasonably be furnished alternatively through other radio services.

The amateur radio regulations offer great flexibility - other radio services are much more tightly controlled. Ham Radio is largely self regulating, and the FCC spends little time or effort overseeing radio amateurs.

Amateur Radio occupies spectrum that is worth billions of dollars in today's market. Why are we allowed to do this?

Title 47 – Part 97 Subpart A—General Provisions
§ 97.1 Basis and purpose.

(a) Recognition and enhancement of the value of the amateur service to the public as a voluntary noncommercial communication service, particularly with respect to providing emergency communications.

(b) Continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art.

(c) Encouragement and improvement of the amateur service through rules which provide for advancing skills in both the communication and technical phases of the art.

(d) Expansion of the existing reservoir within the amateur radio service of trained operators, technicians, and electronics experts.

(e) Continuation and extension of the amateur's unique ability to enhance international goodwill.

History of Amateur Radio:

American Radio Relay League founded in 1914

World War I – US Navy had complete control of radio during the war, hams were ordered to shut down.

Post war, the Navy was inclined to keep its supreme authority over all forms of radio transmission. ARRL lobbied hard to get hams back on the air, which did not happen until November 1919.

Hams were relegated to wavelengths shorter than 200 meters (Frequency > 1.5 MHz), which experts at the time thought were useless for long distance communications. Hams quickly proved the experts were wrong.

Hams making use of things that others considered useless has been a recurring theme over the years. Small satellites were once considered useless...

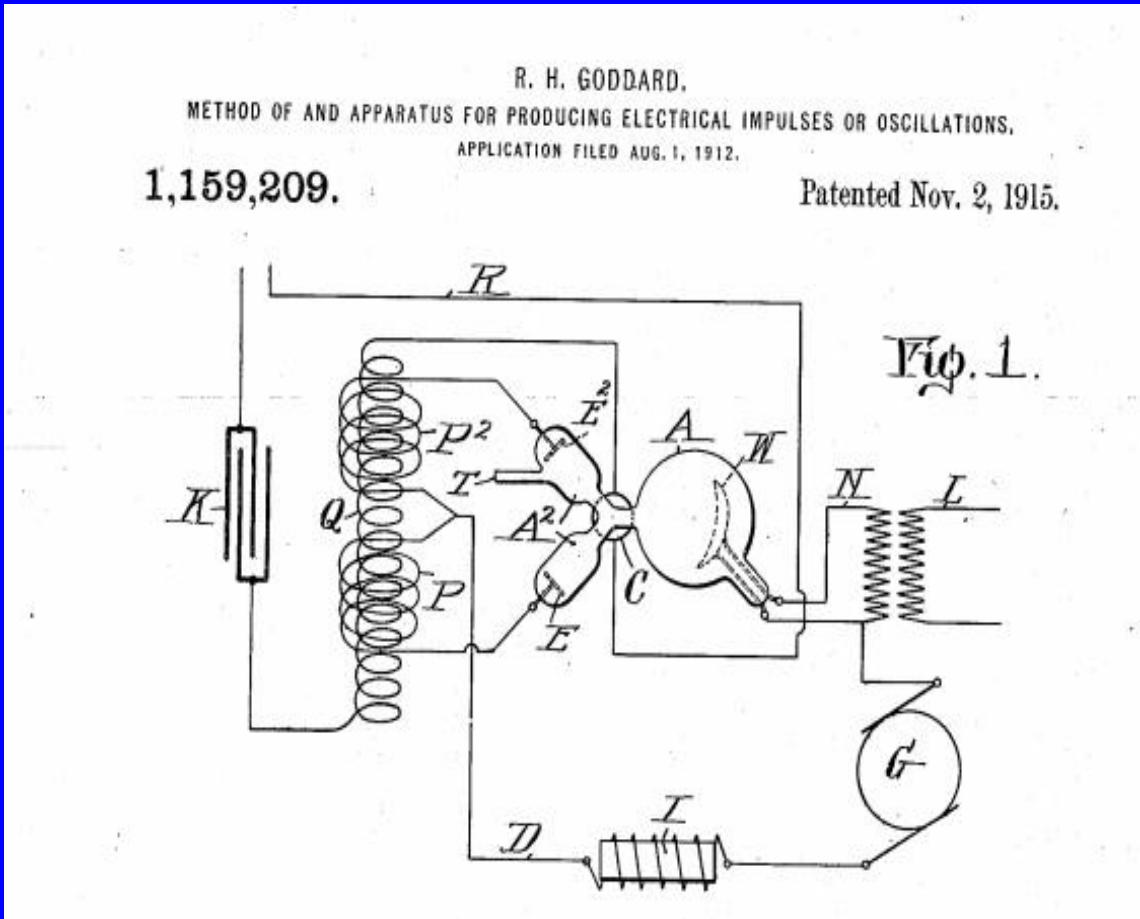
History of Amateur Radio:

Amateur radio in the 1920's

Robert Goddard was not a licensed ham, but he did hold several noteworthy patents in radio technology. In 1920, Goddard started a radio club at Clark University. The radio club became one of the pioneer radio stations in New England.

Robert's cousin, Ralph Willis Goddard, was a well known and very active ham in New Mexico in the 1920's.

A 1924 Collier's article recognized the value of amateur radio in education.


R. H. GODDARD.

METHOD OF AND APPARATUS FOR PRODUCING ELECTRICAL IMPULSES OR OSCILLATIONS.

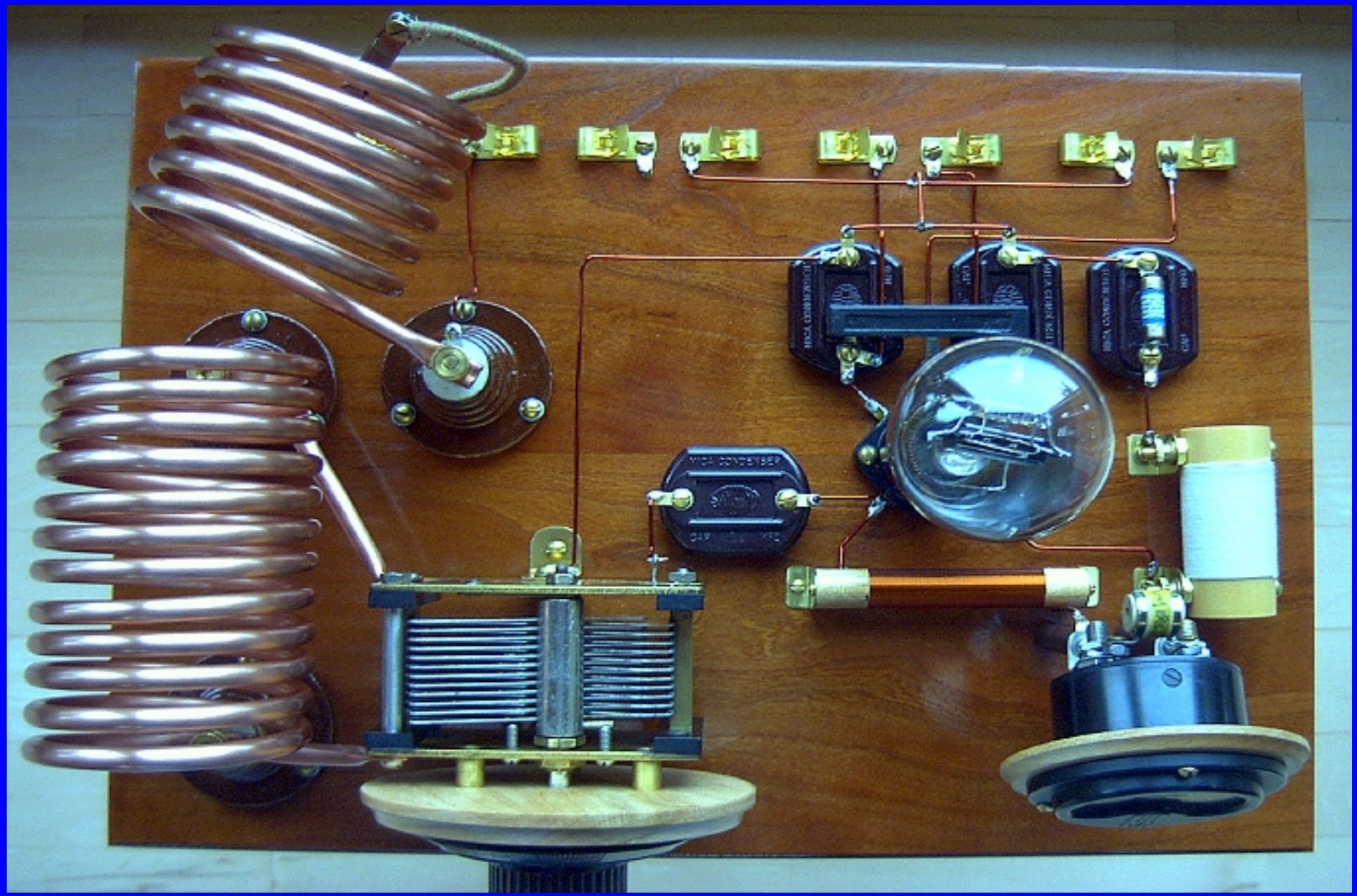
APPLICATION FILED AUG. 1, 1912.

1,159,209. Patented Nov. 2, 1915.

Fig. 1.

History of Amateur Radio:

1930's - Hams weather the great depression, using ingenuity in place of money. The first electronic breadboards were actually made on bread boards!



History of Amateur Radio:

1940's World War II – Ham radio shuts down again for duration of the war, many hams enter military service, companies that manufactured ham equipment before the war quickly switched to government contract work to supply military radio needs.

Post war – Ham radio comes roaring back, fueled by a large supply of inexpensive war surplus radio gear.

1950's – Television broadcasting begins, hams learn to peacefully coexist with their neighbor's newfangled TV receivers, and TV manufacturers learn to design for electromagnetic compatibility.

Sputnik – Soviet Union chose 20 MHz downlink because they knew that tens of thousands of hams around the world would hear it.

History of Amateur Radio:

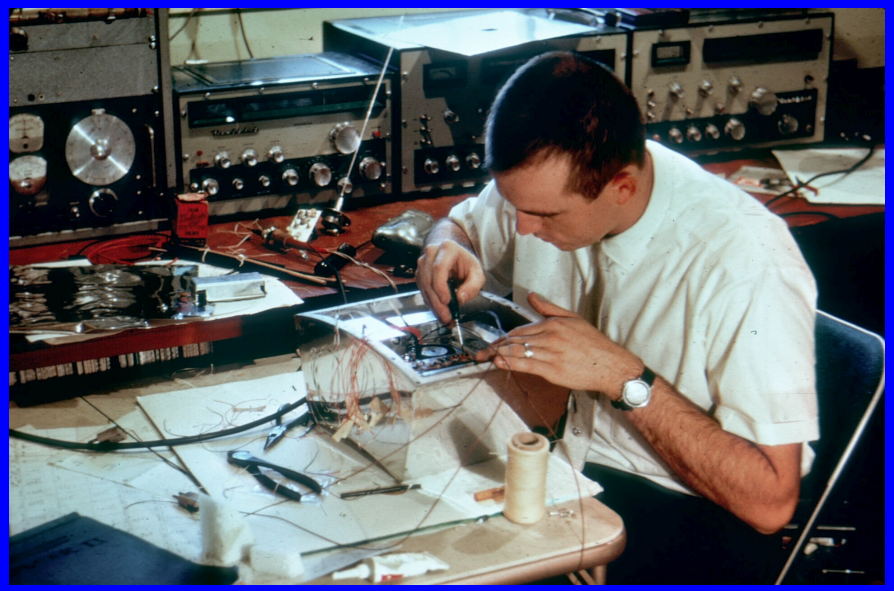
1960 – First two-way amateur moonbounce contact (1296 MHz)

History of Amateur Radio:

1961 – Hams in western US experiment with high altitude balloon flights. An off the cuff suggestion was made to shoot one of those payloads into orbit.

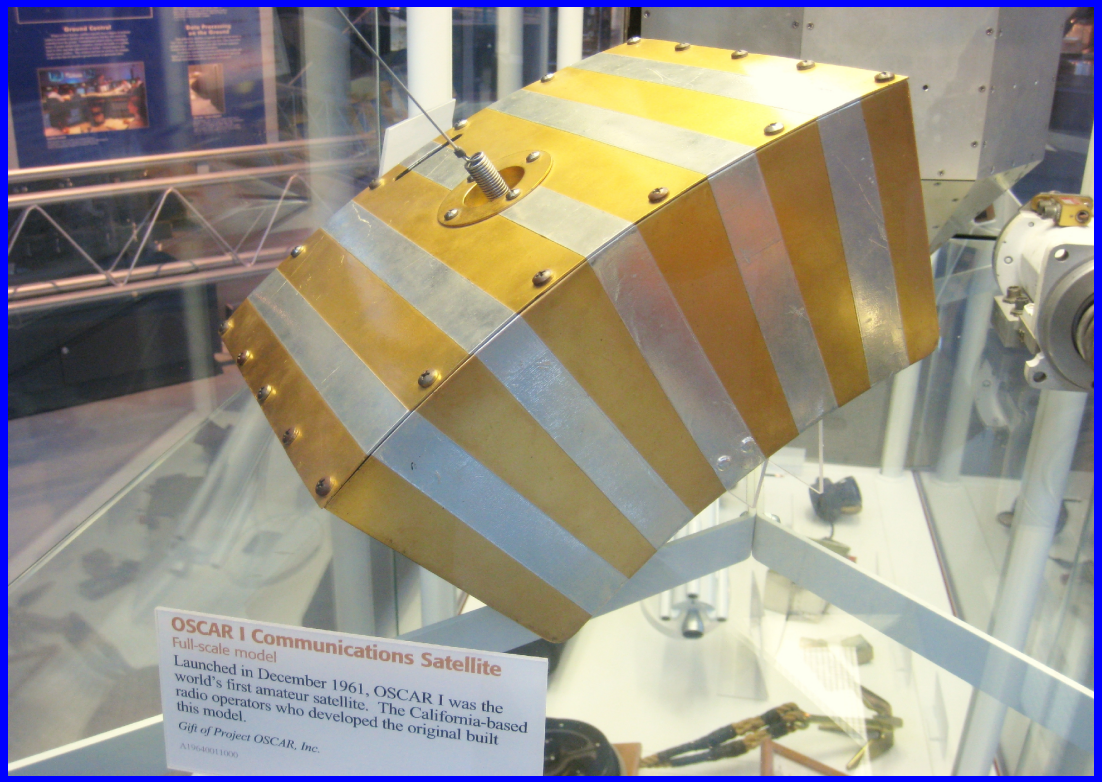
Project OSCAR is founded in California.
OSCAR - "Orbiting Satellite Carrying Amateur Radio"

December 1961 – OSCAR 1
Out of pocket cost of satellite - $64



OSCAR- 1

- Launched December 12, 1961
- Primary mission was a classified USAF Corona imaging satellite
- First satellite not built by a governmental entity
- First satellite to be deployed as a secondary payload
- Bureaucratic effort exceeded technical challenges
- Set the precedent for all future secondary satellites
- Morse code beacon operated for three weeks on battery power



"Getting the early OSCAR satellites approved for launch was a highly political process. I was a 21 year-old just starting out in the field and was tremendously impressed by the talents of the OSCAR Board of Directors. The challenges the board faced in obtaining the permissions from the various government agencies and Lockheed were enormous. We had to keep in mind that ejectable subsatellites were unknown at the time. And, convincing the various agencies that this 'honor' should go to a home built satellite with no official credentials was seen as a big risk. A premature release of the OSCAR satellite would keep the Agena satellite from deploying its booster adapter and would be a catastrophic end to the main mission. There were numerous meetings with government and military representatives, including many well-connected hams. These discussions and the creation of the OSCAR 'White Paper,' helped establish the political and technical credibility we needed to obtain launch permission. The bureaucratic efforts probably exceeded those required to build the satellite." - Lance Ginner, Project OSCAR

There is little for a project manager to gain, and a lot to lose, by carrying a secondary payload. Someone in high authority really believed that amateur satellites were worth supporting.

What could possibly go wrong? Oscar 3, March 9, 1965:

"While observing the launch from the small tracking station and listening to the launch commentary, we got a report that the deployment switch for the OSCAR 3 satellite showed “deployed”. If this were true, then the entire mission was going to fail as the OSCAR would wedge between the Agena space vehicle and the booster adapter and keep it from separating and performing the final rocket burn to orbit. The next few minutes were the worst of my life. If the telemetry was correct then that would be last of the OSCAR program (and probably my career as well) as I had designed the deployment mechanism and “certified” the spacecraft was qualified. Fortunately the separation was successful and later investigation found that the separation indicator switch on the Agena side of the interface had been misadjusted prior to launch."
- Lance Ginner, Project OSCAR

1969 – Radio Amateur Satellite Corporation (AMSAT) incorporated in Washington DC as a 501 (c) (3) nonprofit educational organization to carry on the pioneering work of Project OSCAR.

Many Goddard folks were involved in formation of AMSAT

• First AMSAT project was refurbishment and launch of Australis-OSCAR 5 satellite, built by University of Melbourne, Australia.

There was great resistance from the TIROS project but NASA HQ declared that it should fly.

• Built and launched OSCAR-6, launched piggyback with ITOS-D.

First complex control system using discrete CMOS logic.

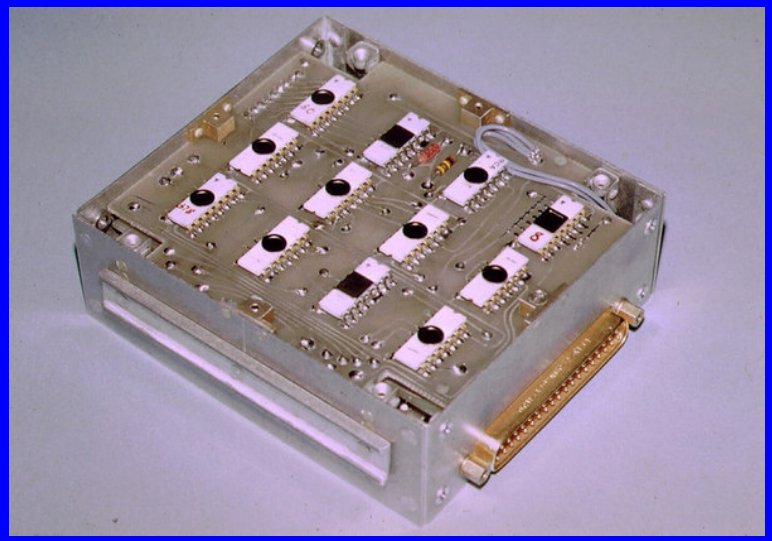
Demonstrated Doppler location of ground station for search and rescue, leading to the COSPAS / SARSAT rescue system, also demonstrated relay of medical data from remote locations.

- OSCAR-7

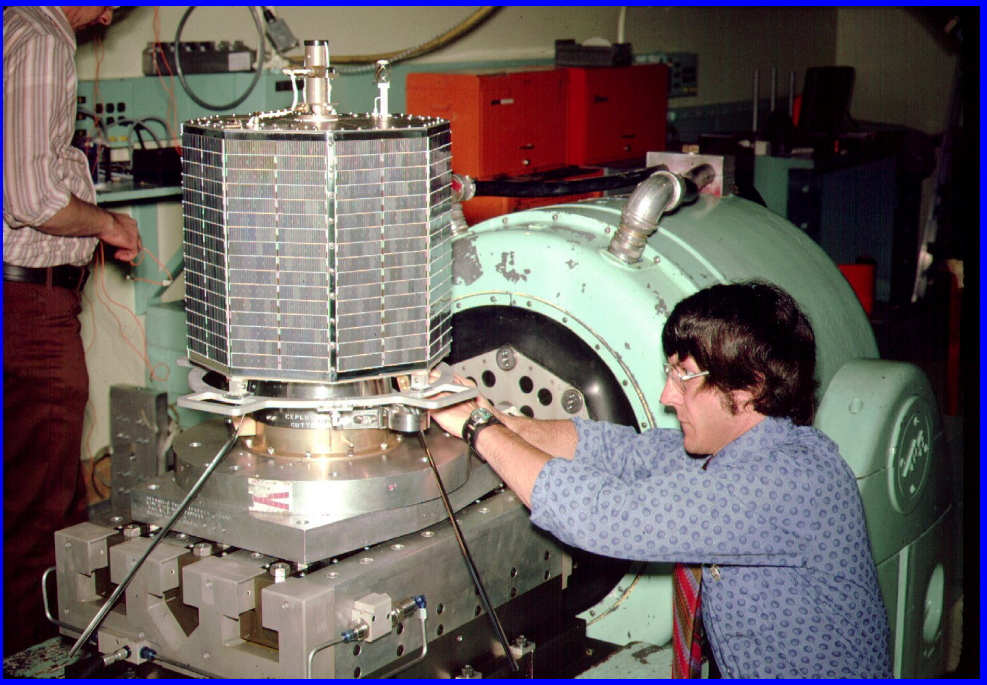
Launched November 15, 1974 with NOAA-4

First satellite-to-satellite relay, through OSCAR-6

Battery shorted in 1981 – battery was engineering unit from Radio Astronomy Explorer



OSCAR-7 command decoder made with 4000 series CMOS



Left: Jan King mounts OSCAR-7 on the shake table at Goddard in 1974.

Right: The battery short cleared itself in June 2002, allowing the satellite to come back to life. OSCAR–7 continues to operate while in sunlight and is now the oldest working satellite in Earth orbit. It is estimated to have absorbed over 100 kRads(Si) during its 40 years in orbit.

UoSAT-OSCAR 9, first satellite from University of Surrey. A young student named Martin Sweeting built his first satellite with AMSAT.

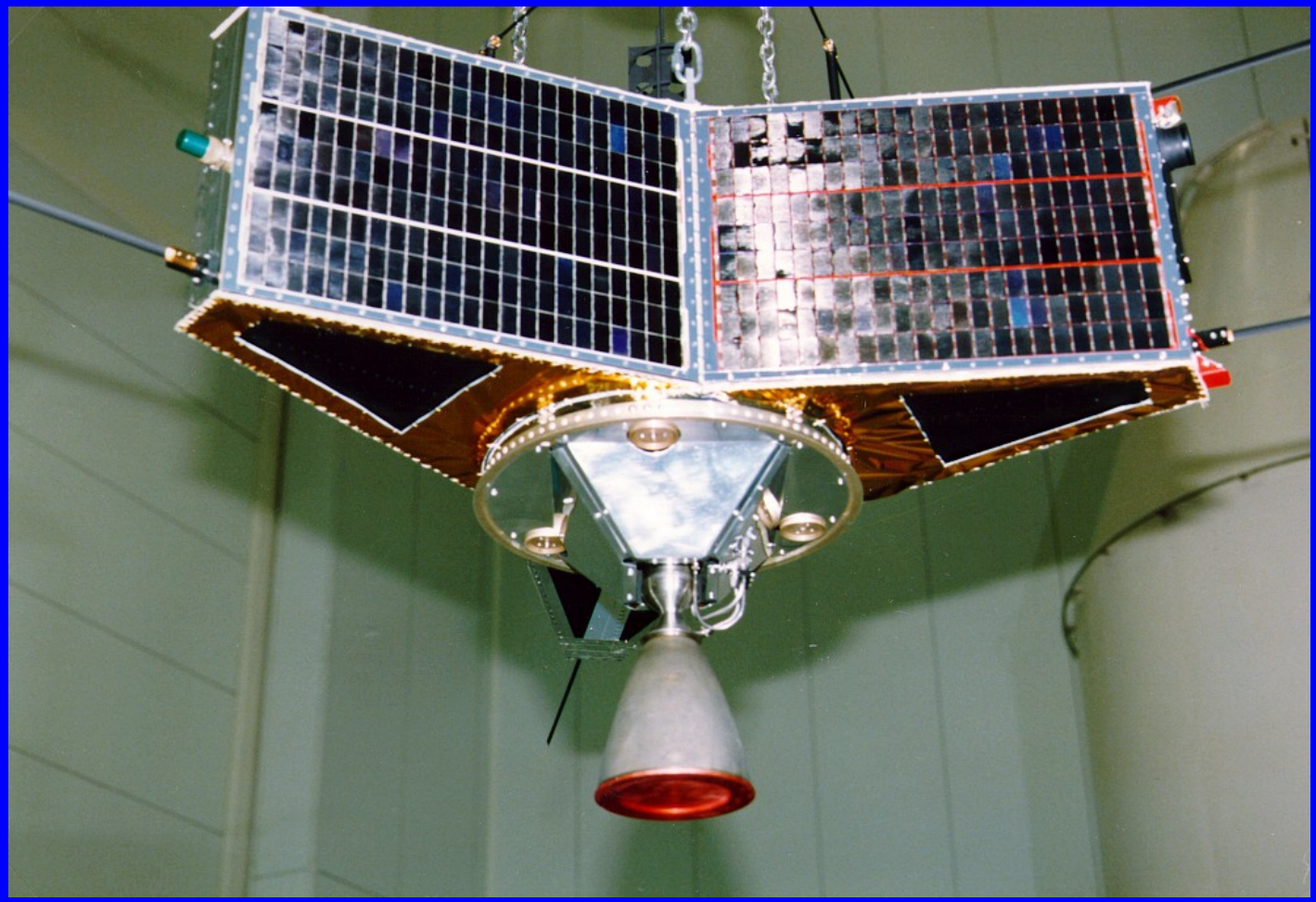
1980's - Phase 3 program - high altitude satellites to offer hours of coverage to large parts of the northern hemisphere.

Phase 3A - assembled at Goddard Visitor Center
Launched May 23, 1980 - Ariane 4 first stage launch vehicle failure

Phase 3A in the AMSAT lab at the Goddard Visitor Center, 1980
The base of the Delta rocket is visible outside the window.

Phase 3B - Assembled at AMSAT-DL in Marburg Germany
Launched June 16, 1983 and renamed OSCAR-10
Computer operated for three years before succumbing to radiation

Phase 3C - Assembled in Boulder, Colorado,
Rad-hard RCA1802 CPU from Sandia and memory from Harris
Launched June 15, 1988 and renamed OSCAR-13



Long term analysis of orbital behavior showed a previously unexpected lunar-solar resonance effect, which caused AO-13's perigee to drop inside Earth's atmosphere, leading to reentry in December 1996. Satellite electronics systems were working well at time of reentry.

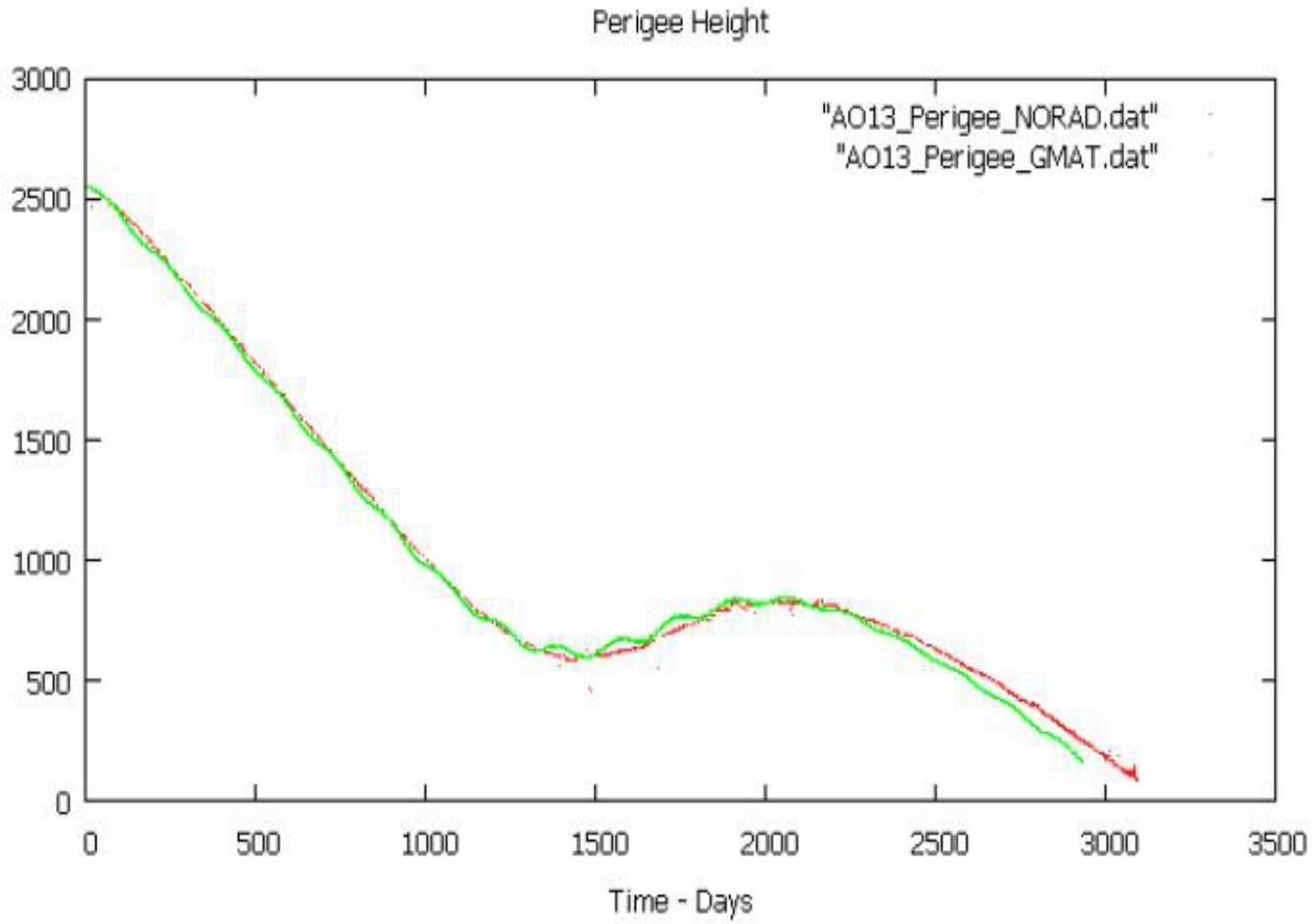


Figure 2: AO-13 perigee height as calculated by GMAT plotted with NORAD tracking data.

Orbital behavior is chaotic and highly sensitive to initial conditions. A small change in initial RAAN would have extended AO-13's lifetime for several more years.

If a future Molniya satellite were to carry a small electric thruster, could we make small adjustments to the orbit to set up a desired reentry date? Simulations are in work with NASA's GMAT program.

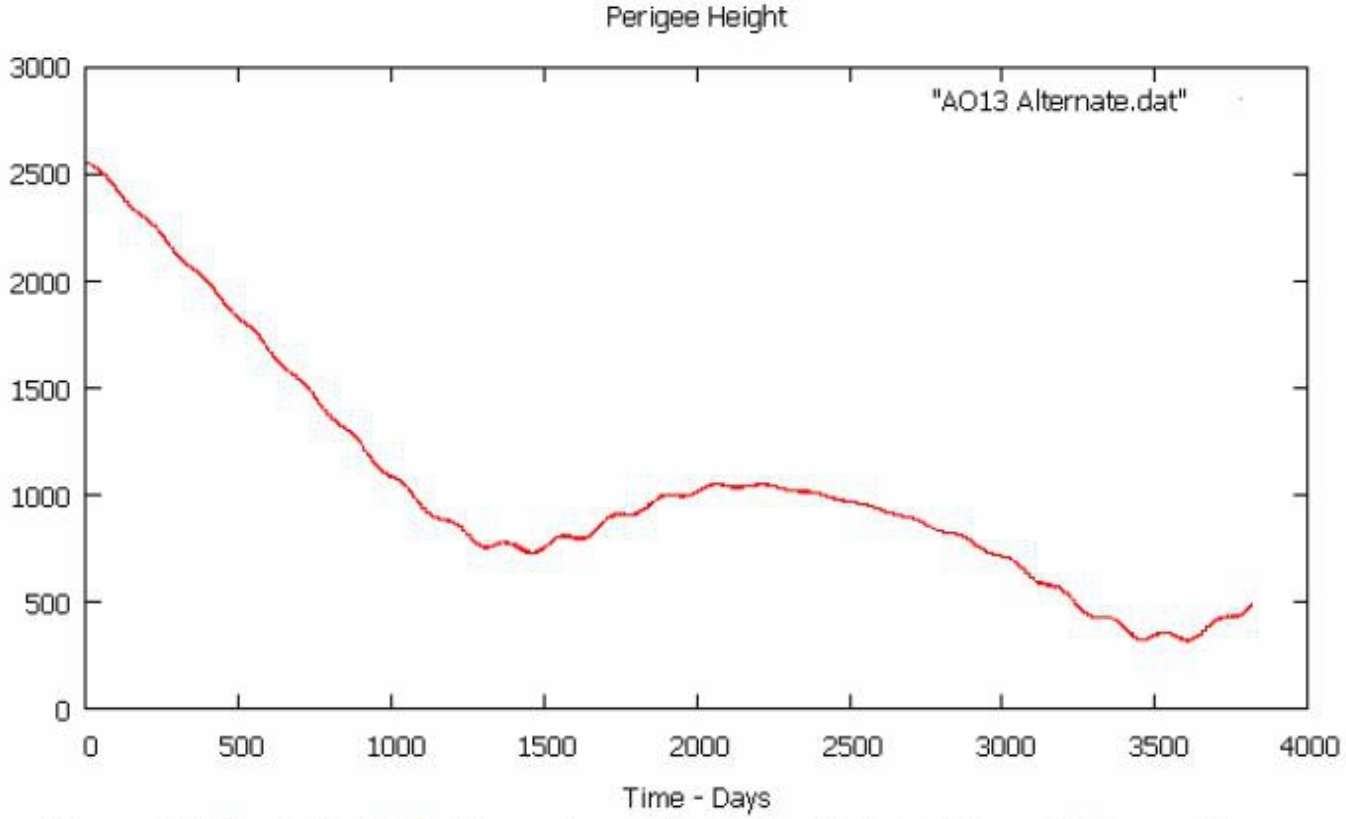


Figure 5: If the initial Right Ascension of Ascending Node had been 15 degrees less, AO-13 perigee height would have remained above 400 km throughout 1998

1983 - First Ham in Space operation

Owen Garriot W5LFL on STS-9 Spacelab 1

Owen was licensed as teenager growing up in Oklahoma. Amateur radio led him to a career as an ionospheric physicist at Stanford and later a NASA Scientist-Astronaut.

Goddard's own Ron Parise, WA4SIR, operated the third "Shuttle Amateur Radio EXperiment" (SAREX) mission in the fall of 1990.

As the International Space Station became operational, SAREX transitioned to become the ARISS program.

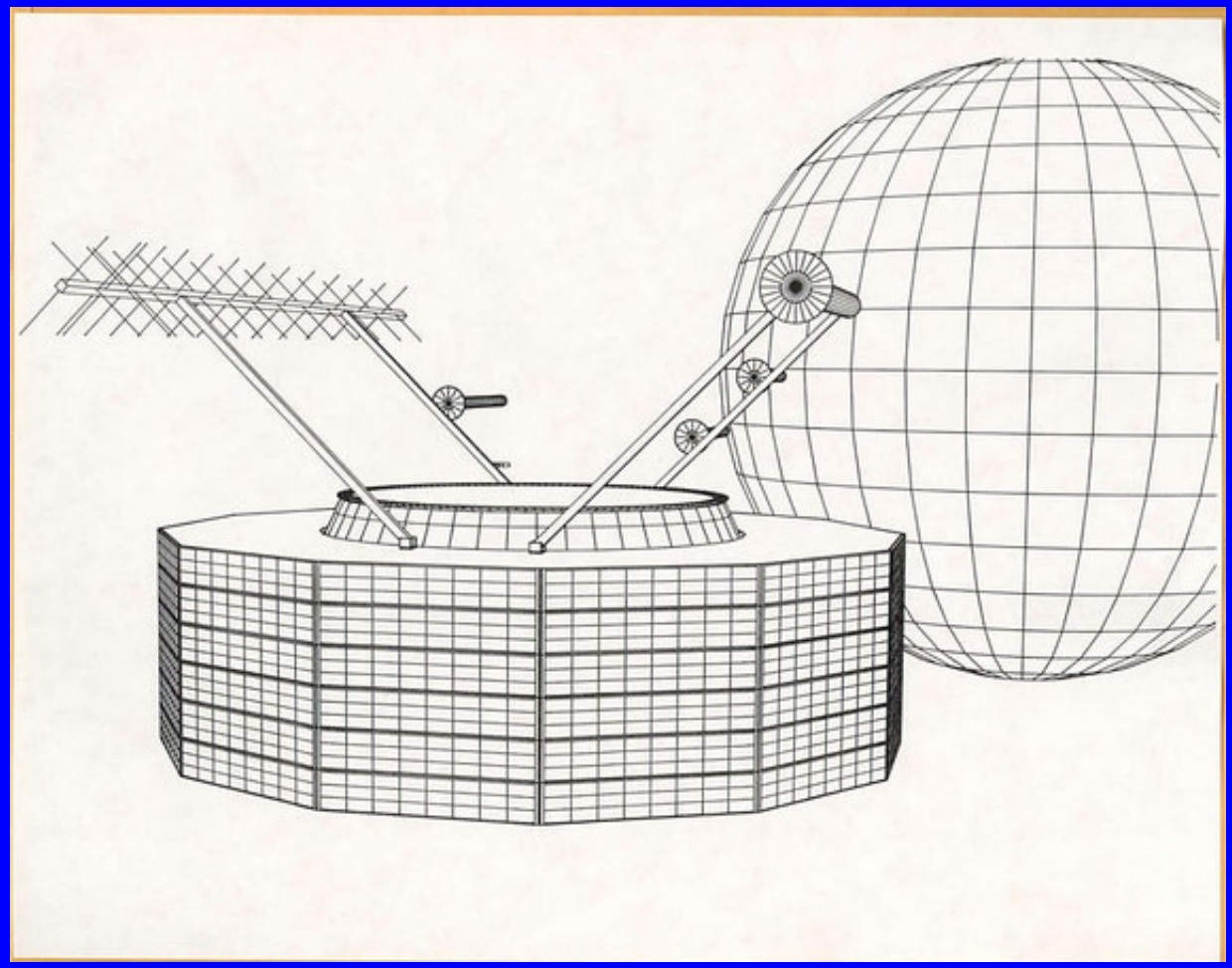
Bill McArthur, KC5ACR, operating the ARISS equipment in the Russian module

Susan Helms, KC7NHZ, was a very active ham radio operator during her ISS expedition.

An AMSAT designed ham radio antenna is mounted on the exterior of the Columbus module. The EVA friendly antenna elements are made of Kapton covered flexible steel tape.

ARISS has supported over 900 scheduled school contacts since 2001.

1990 – European Space Agency offers AMSAT a 600 kg launch on the first Ariane V mission.



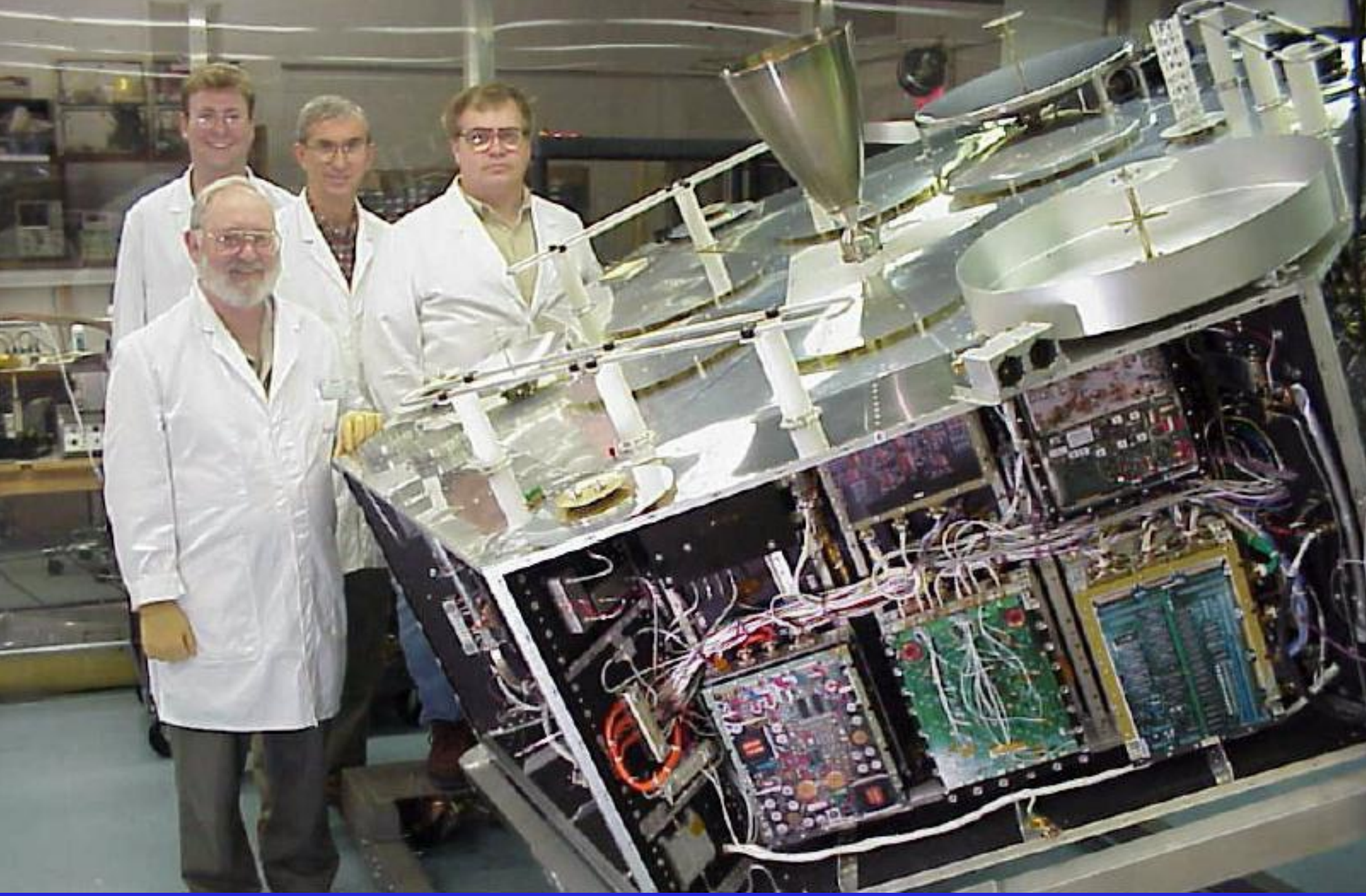
Design concept for a proposed geosynchronous satellite (Phase 4).

But a Molniya orbit offers worldwide coverage and financial support.

Phase 3D – A 600 kilogram (wet mass) satellite with a 400 Newton hypergolic propulsion system.

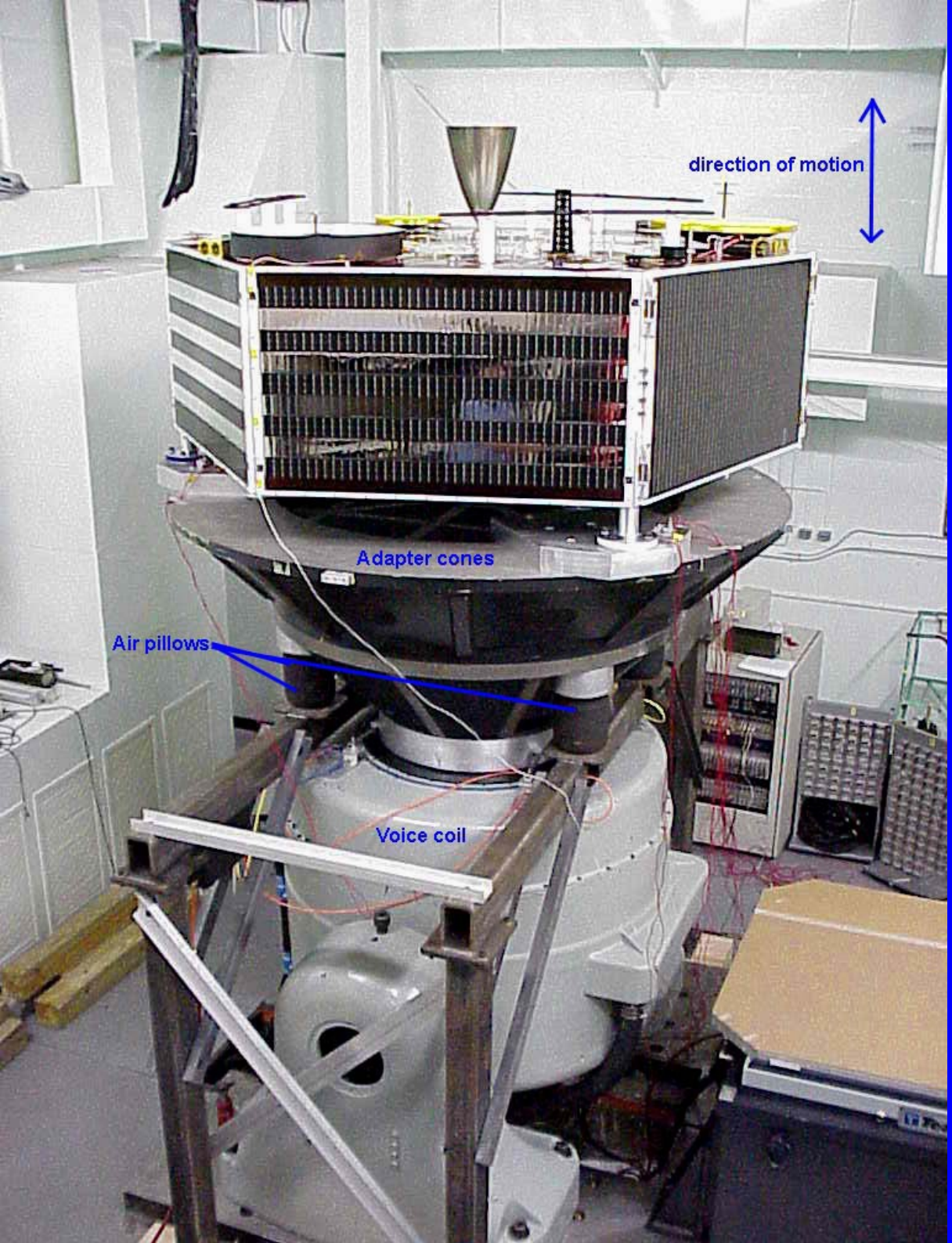
Built by volunteer labor from AMSAT organizations in a dozen different countries.

$3.5 million budget raised mostly from individual contributions in $50 or $100 increments from hams around the world

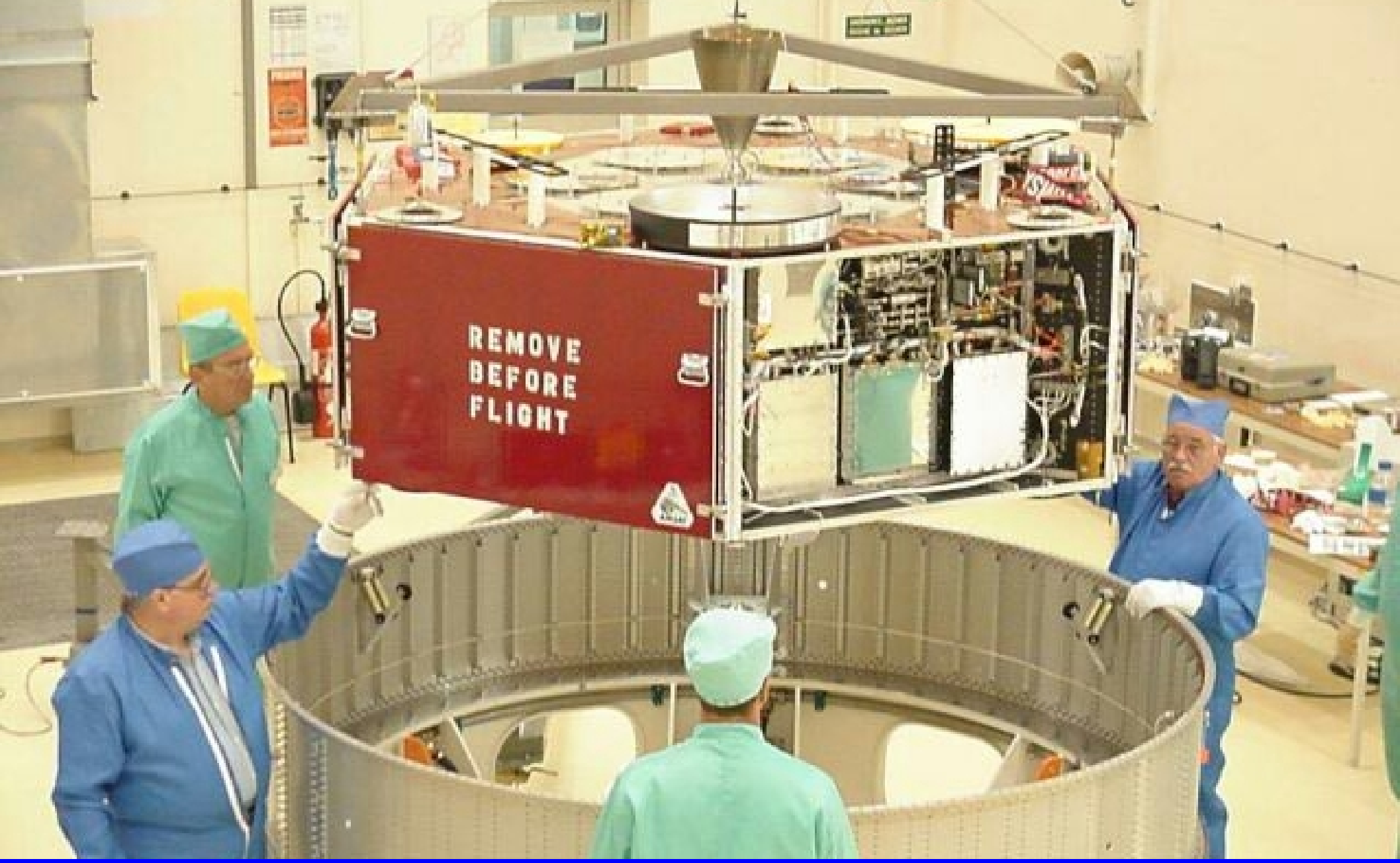


Phase 3D was assembled at the AMSAT satellite laboratory in Orlando Florida, near the airport

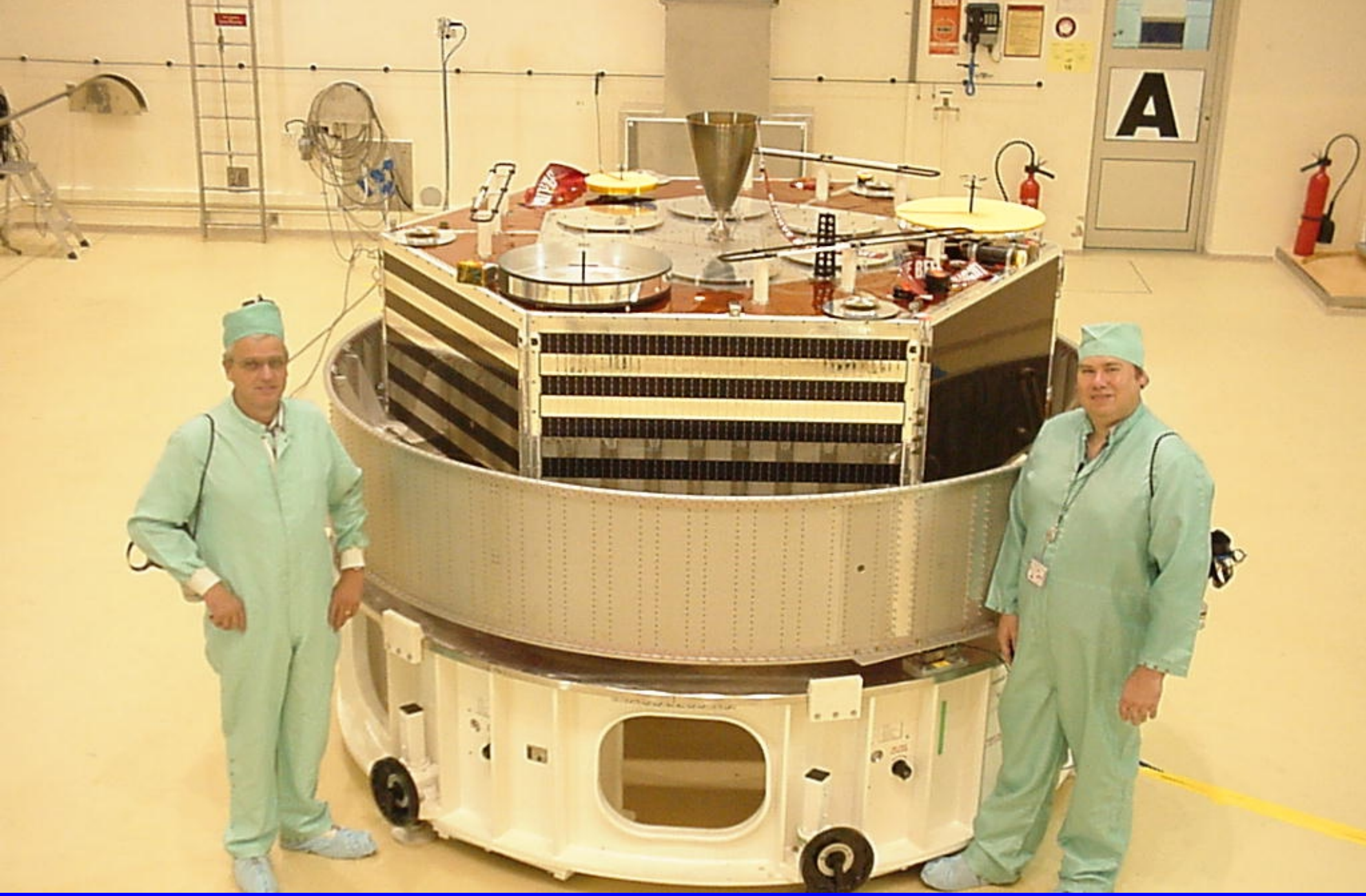
Thermal vacuum test at Orbital Sciences, Germantown MD, Fall '98



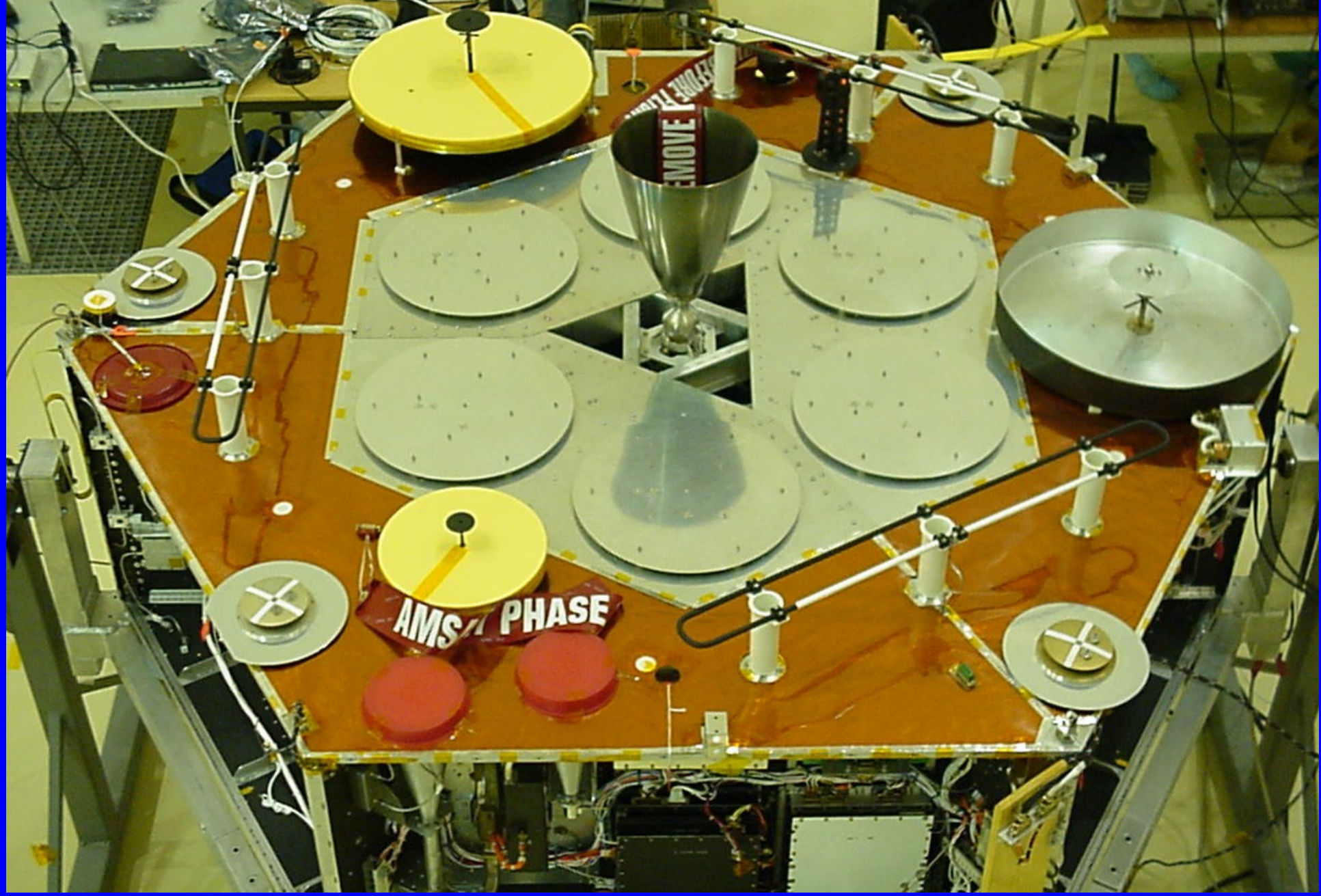
Phase 3D on shake test apparatus in GSFC Building 7 August 1999



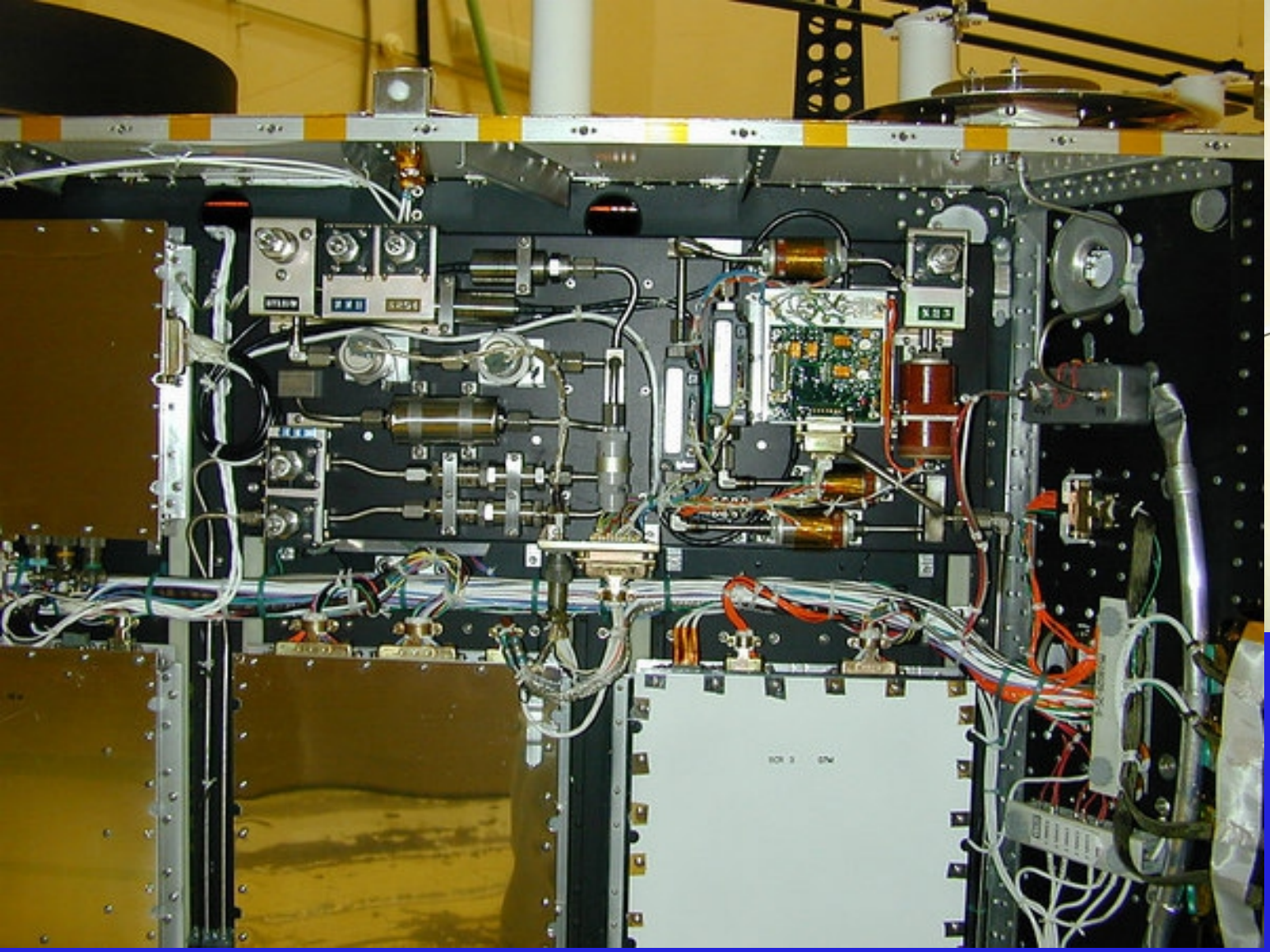
Final Assembly at Kourou. The AMSAT-designed Specific Bearing Structure (SBS) raises the adapter cone by 60 cm, making room for Phase 3D – The SBS supports the entire weight of the primary satellite payload. ESA trusts AMSAT not to destroy their rocket.



Final Assembly at Kourou. AMSAT Phase 3D satellite loaded into the Specific Bearing Structure, ready for mating with the Ariane V rocket.



The antenna farm on the top of the satellite included antennas for every amateur band from two meters to 24 GHz. The L band reflector on the right is a re-purposed cake baking pan from the housewares department at Kmart.



Phase 3D propellant flow assembly built by Dick Daniels, W4PUJ. Dick's degree was in business administration, he worked at NASA headquarters in contracts and finance for 33 years, and probably built more space flight hardware than anybody else who ever worked at headquarters.

Highly toxic fuel and oxidizer ignite on contact. This satellite is a live bomb, but ESA trusted AMSAT not to blow up their rocket. Dick and two ESA technicians are loading propellent into P3D.

Phase 3D was launched November 16, 2000 on the third Ariane 5 and renamed OSCAR-40.

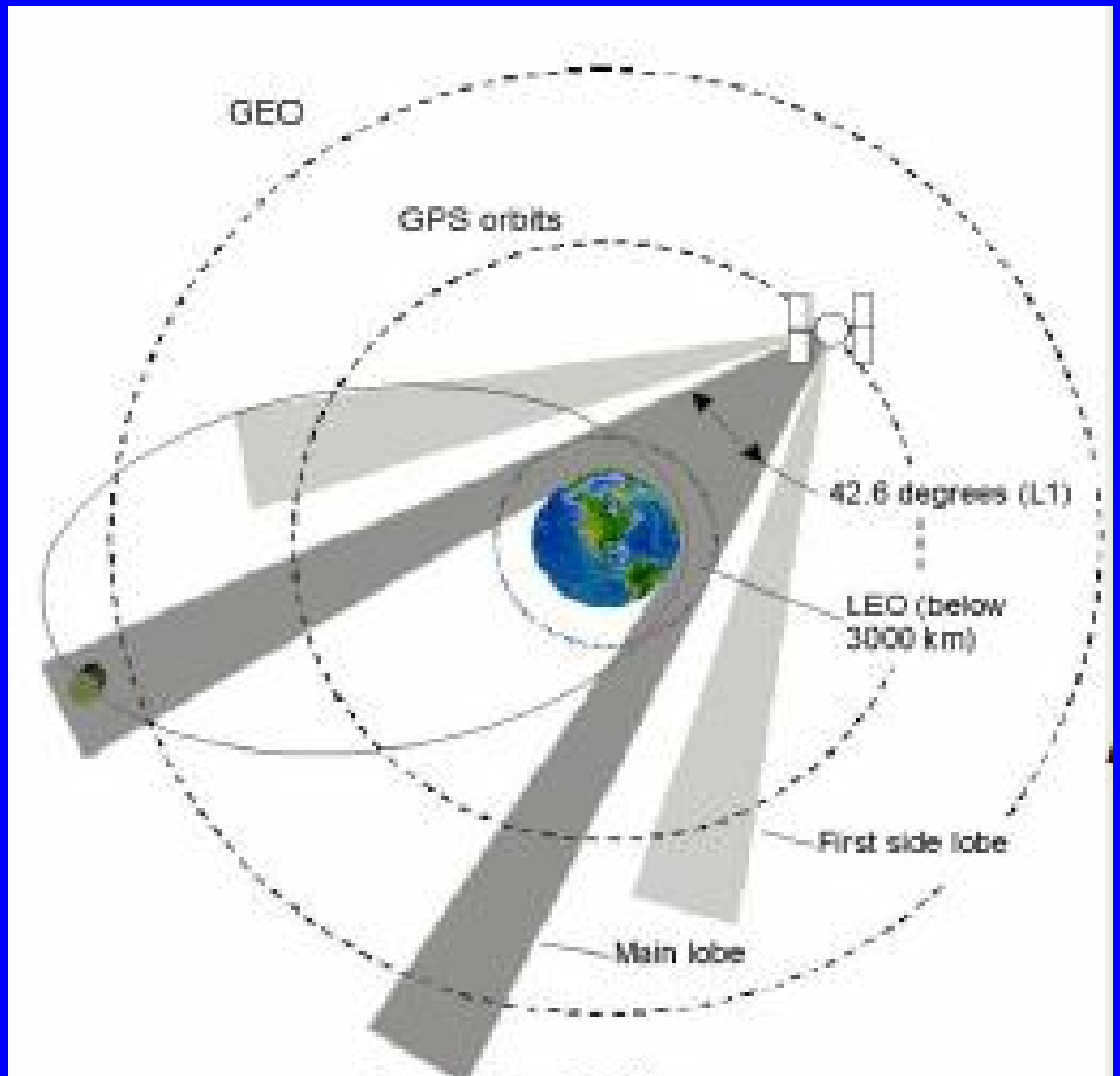
Explosive event occurred during first motor firing on December 13. It was traced to the failure to remove a small plastic cap from a propellent valve exhaust port.

Satellite operated until January 2004, although some transponders never worked.

In 2004, a main battery short circuit, possibly caused by the explosion, shorted out the power bus.

We still listen for signals from time to time, should the battery short clear itself someday.

OSCAR 40 carried a Goddard-sponsored GPS receiver, which made the first long term measurements of GPS signals above the constellation. Data resulted in GPS Block III requirements modification, ensuring the robust use of GPS-based navigation for future missions above the GPS constellation



21st century – New Challenges for AMSAT

1. No more free launches

AMSAT was once the only small satellite organization in the world.

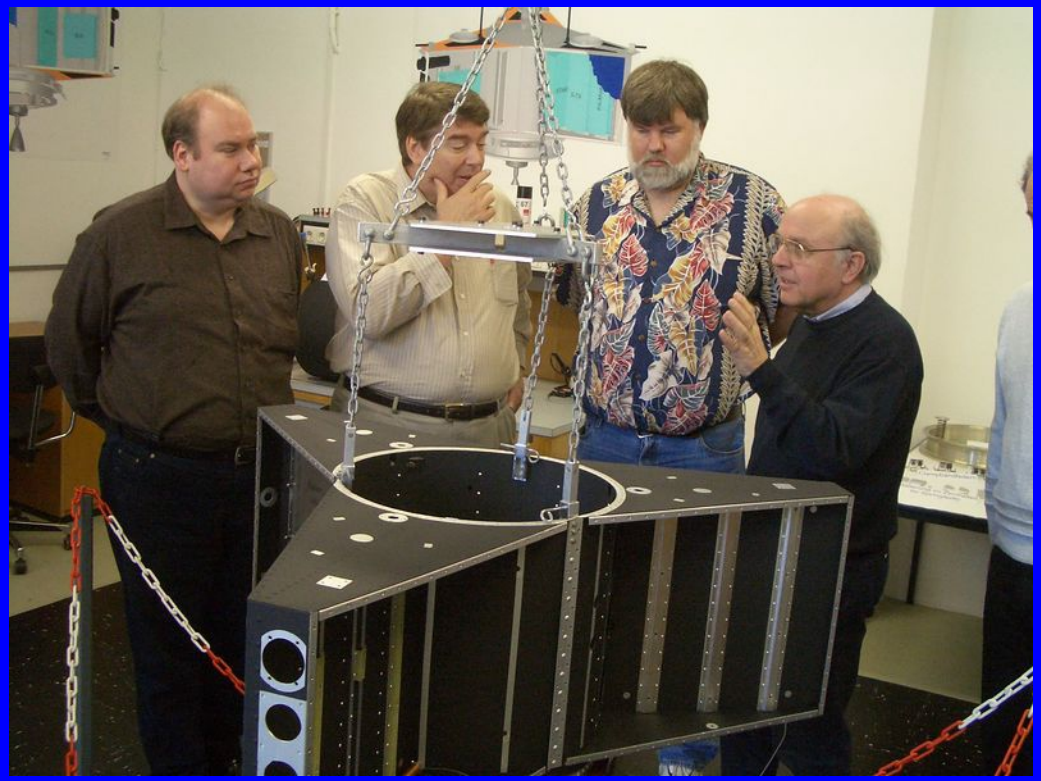
Then Surrey Satellite Technology Limited (SSTL) was founded (by Martin Sweeting, an AMSAT alumnus).

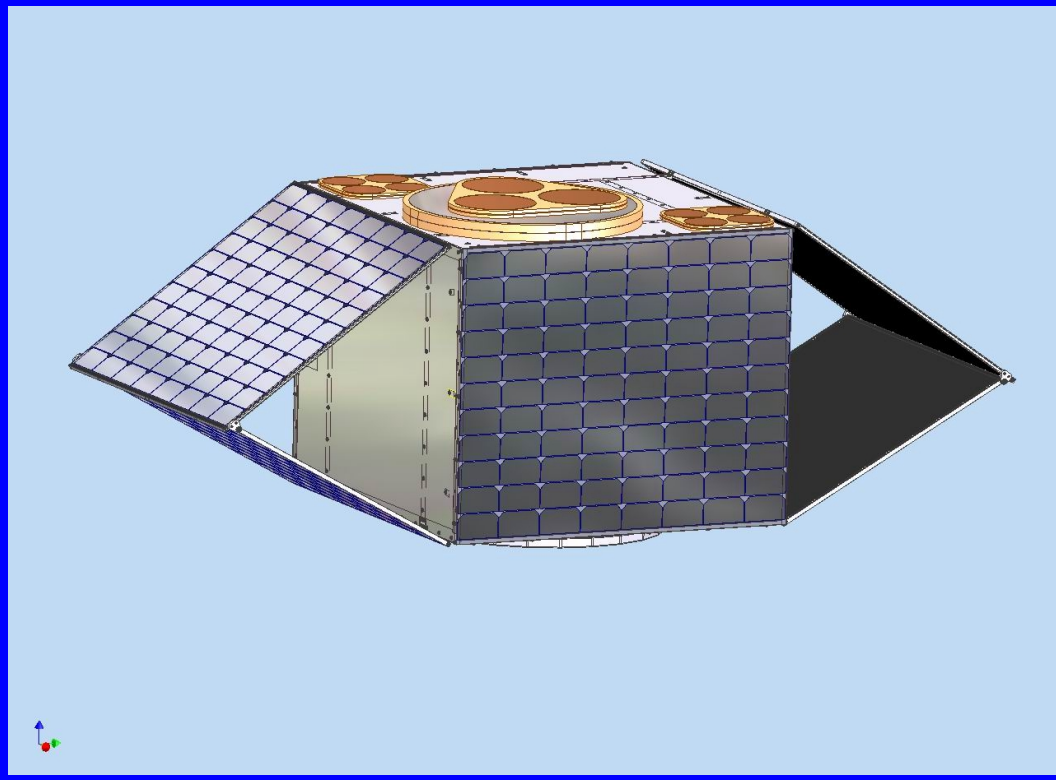
Then Cubesats were invented (by Bob Twiggs, an AMSAT member)

AMSAT and Project OSCAR created the small satellite industry, and now we must compete for launches with this industry.

A Brief History of Rideshares (and Attack of The CubeSats)

Michael A. Swartwout
St. Louis University
3450 Lindell Blvd
St. Louis, MO 63103
314-977-8214
mswartwo@slu.edu





AMSAT Germany built Phase3E in 2004, it is still looking for a ride.

AMSAT “Eagle” was a proposed 100 kg HEO satellite to replace some of AO-40's functionality – it never got close to finding a launch.

Ironically, it was AMSAT and Project OSCAR's early work that largely proved that small satellites are useful, now everybody is building and launching them.

21st century – New Challenges for AMSAT

2. Loss of radio spectrum

Commercial pressure for release of more microwave spectrum is causing governments around the world to revoke amateur radio access to the microwave bands. We have a hard time holding on to these frequencies if we cannot launch the satellites that use them.

Southgate Amateur Radio News

Page last updated on: Saturday, September 29, 2012

Sweden loses 2.3 GHz band

Swedish radio amateurs have lost the 2300 MHz band although they have gained some spectrum at 1.8 MHz.

The **Swedish Amateur Radio Society** (SSA) has announced the loss of the 2300 MHz band with effect from October 1. 2400-2450 MHz is still allocated for amateur radio operation but the power there is limited to just 100 milliwatts at the antenna.

21st century – New Challenges for AMSAT

3. International Traffic in Arms Regulations (ITAR)

AMSAT is now an international munitions dealer!

The State Department really doesn't understand the concept of satellites built by hobbyists.

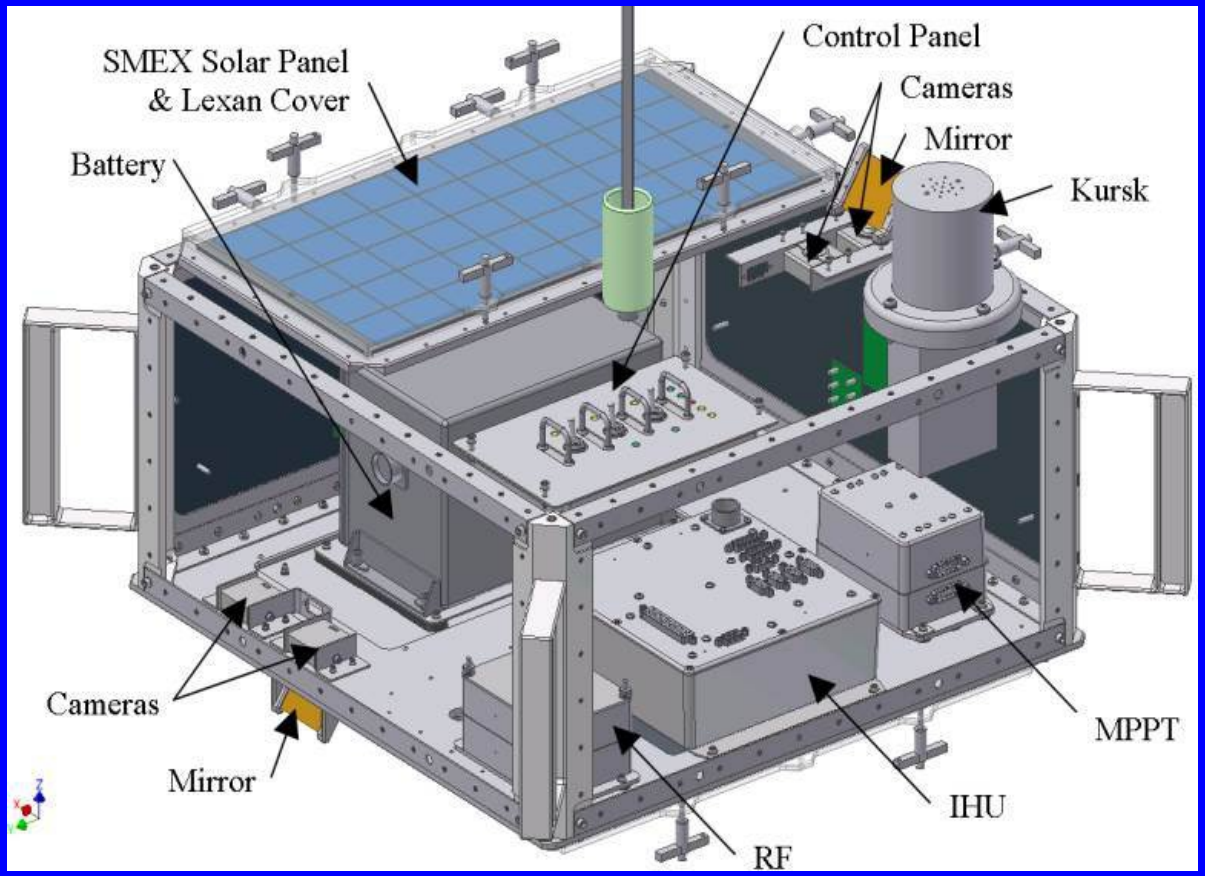
Phase 3D / OSCAR-40 was a collaboration of AMSAT organizations from a dozen different countries in a pre-ITAR environment. Building this satellite would have been impossible under present day ITAR rules.

ITAR has forced AMSAT-North America to disengage from other AMSAT organizations around the world, and destroyed the international cooperation that made complex projects possible!

In one recent year AMSAT spent more money on legal fees than it spent on satellites.

New missions for AMSAT:

ARISSat-1 was deployed from the Russian airlock of the ISS on August 3, 2011, and reentered on January 5, 2012. It carried technology demonstrations and student experiments. A second ARISSat frame is available if a suitable mission is defined for it to fly.

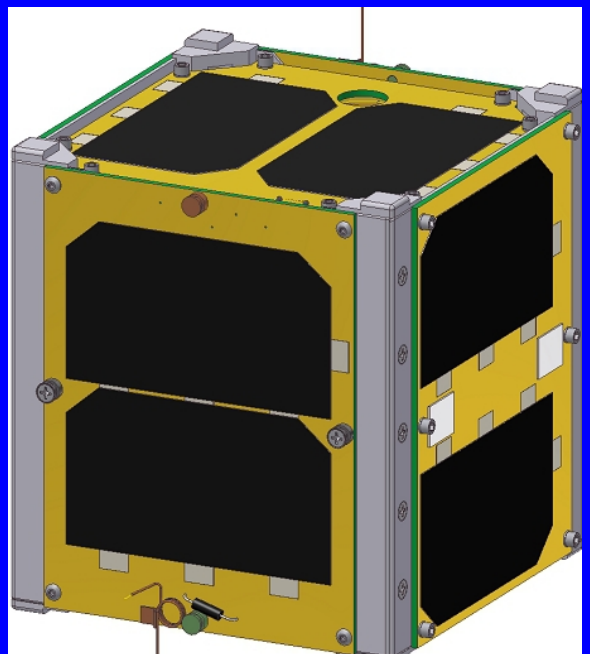


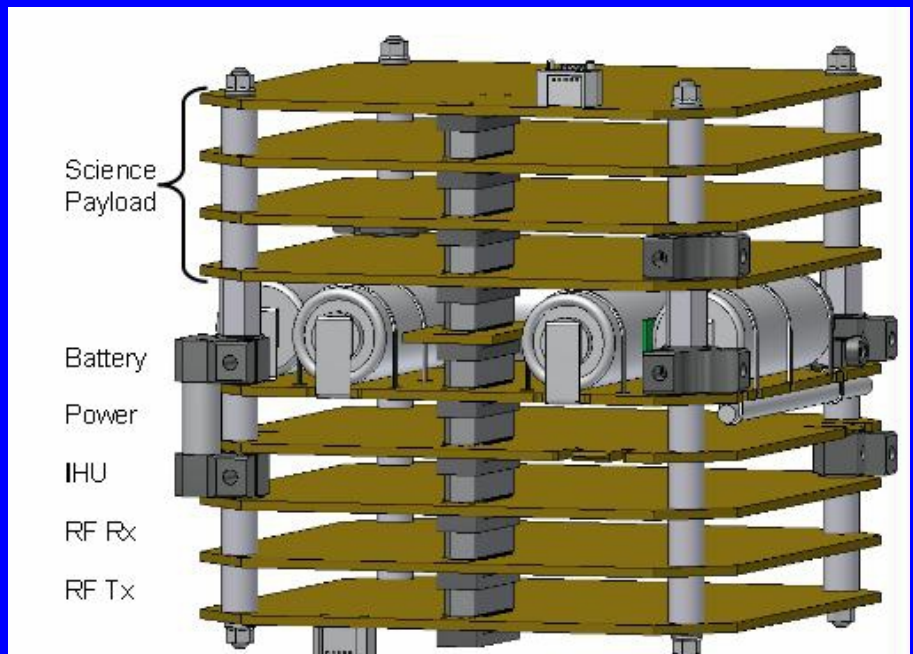
New missions for AMSAT:

Fox-1 is a 1U Cubesat designed for LEO orbit, manifested on a NASA ELaNa launch with an NRO mission in spring 2015. Currently undergoing testing and certification for launch.

Fox-2 is a second 1U Cubesat carrying a Vanderbilt University radiation effects experiment and single channel amateur radio transponder, also selected for ELaNa launch.

Fox-3 is a third 1U LEO Cubesat to be launched commercially for $100K – AMSAT is now fund-raising for this launch.





New missions for AMSAT:

Low Earth Orbit missions offer very short pass durations, and a limited number of users. Hams would like to have another high altitude satellite like AO-10, AO-13, AO-40.

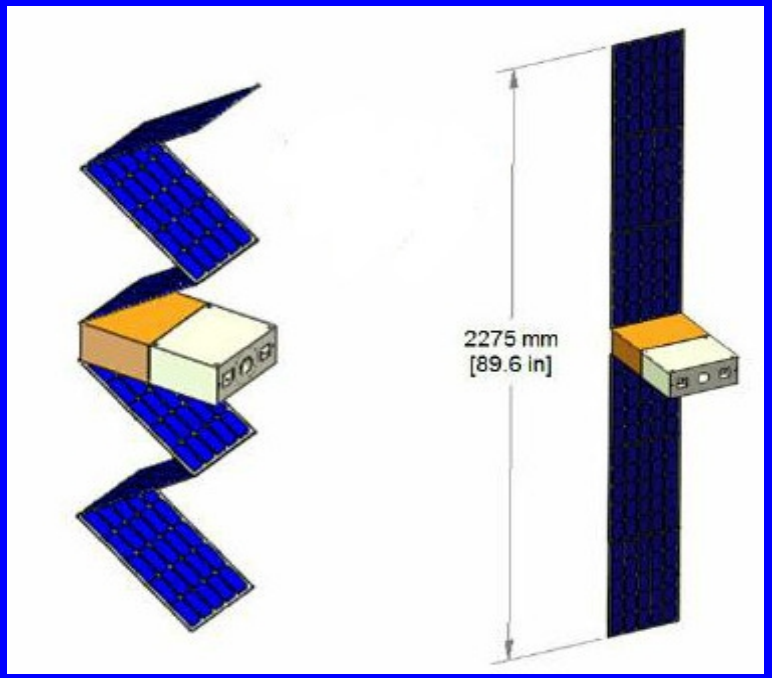
Ideally we could launch a new satellite every few years to replenish the constellation and encourage radio amateurs to invest in ground station antennas and equipment that will not become obsolete.

The commercial rate for a 3U Cubesat launched to GTO starts at $750K. To obtain a NASA sponsored Cubesat launch, we need to have a mission that fulfills one of NASA's objectives under the ELaNa program. Amateur Radio communications is not one of NASA's objectives.

AMSAT seeks partnerships with science and technology organizations to carry a small payload in return for a NASA sponsored launch. Could the magnetospheric science community use a few extra particle or field sensors scattered around the Van Allen Belts? Do you have a technology demonstration to launch into GTO?

Can we squeeze the functionality of AO-13 into a 6U sized shoebox? - The answer, I think, is yes, if we have deployable, steerable solar arrays and three axis attitude control. AO-13 was a spinning satellite with body mounted solar panels. It was large enough that we could tolerate such inefficiency in the name of simplicity.

A Busek engineer that I talked to thinks that a 6U satellite should be able to generate 100 watts of electrical power. Rejecting 100 watts of waste heat from a 6U sized satellite will be challenging.



New missions for AMSAT:

HEO is different from LEO, more like the problems of cislunar or interplanetary space- Cubesats that work well in LEO need to be redesigned for missions farther from Earth.

LEO -
Easy communication with simple antennas
Warm Earth fills half the sky
Benign radiation environment
Strong magnetic field for attitude control

HEO -
Directional antennas and higher transmitter power
Thermal environment is challenging
Difficult radiation environment
Weak magnetic field requires more complex attitude control

Technology needed for a HEO satellite is similar to what is needed for Lunar or Interplanetary Cubesat missions. AMSAT's technical challenges are closely aligned with those building such missions.

Work done by ARRISsat and Fox teams can go directly into this mission:

Software defined radio transponder
Power system with maximum power point tracker
Flight computer

but there are additional challenges:

Three axis attitude control
Solar array deployment mechanism
Solar array drive mechanism and rotary slip joints
Thermal design
Deployable high gain antennas

And then there is Radiation!

AMSAT Organization and management:

AMSAT is not a hierarchy – management cannot order people to do things. When a member sees a need to do something, he steps forward and does it. This system actually works pretty well.

AMSAT's volunteers are driven by their passion and love of space flight. The value of donated labor cannot be counted but is very high.

Fund raising efforts are not unlike your local public radio station. (but no on-air pledge drives).

AMSAT members are everywhere, even the NRO.

We are not a space advocacy organization, like The Planetary Society or the National Space Society.

We are a ham radio organization, we go to ham radio conventions, not space conventions. We have tried to promote AMSAT to the space advocacy groups but found little interest.

AMSAT Quality control and parts selection philosophy:

AMSAT missions are similar to NASA Class D missions, with similar parts selection philosophy.

Eliminate gold plating and MIL spec, except in places where it is justified (power relay).

Avoid human handling of parts - testing reduces quality.

Paperwork and documentation not excessive. The Phase3D “Red Book” is only two inches thick.

AMSAT has never launched a "dud" satellite.

AMSAT's business office recently moved to Kensington MD, just off of Connecticut Avenue, after 30 years in Silver Spring

Martha has been AMSAT's office manager for over 30 years. She keeps the business office well organized and running smoothly.

Why work with AMSAT? We have

- A world-renowned volunteer engineering staff.
- Command uplink stations on three continents.
- Worldwide network of radio amateurs for tracking and telemetry.
- Educational and public outreach.
- Student involvement.

Appropriate use of amateur frequencies - AMSAT's position:

Mission must be not for profit.
Data formats must be made public.
Proper notification must be made (IARU).
Significant involvement by licensed radio amateurs.

Since this is a ham radio mission, use of amateur frequencies is appropriate. AO-40 used amateur frequencies to downlink data from the Goddard GPS experiment.

Amateur Radio licenses are issued to individuals, not to organizations.

32nd Space Symposium and Annual Meeting

October 10-12, 2014

Baltimore, Maryland

DoubleTree Hotel – BWI Airport

890 Elkridge Landing Rd, Linthicum, Maryland, 21090

Please come and meet the AMSAT team this October at the AMSAT Space Symposium. It only comes to this area about once every five years, so don't miss it! Online registration is at www.AMSAT.org

Goddard Amateur Radio Club open house October 15 5:30 pm

Club located in area 100 on Beaverdam Road,
near the softball fields.

Live demonstrations of satellite operations.

Cookout on the grill with burgers and muchies.